OHIO RIVER BASIN PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 40*

Sixth Progress Report
for the Period
September 30, 2000 through March 31, 2001

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
Silver Spring, Maryland

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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

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I. STUDY OVERVIEW

A. Purpose and Scope

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is performing a precipitation frequency study to update Technical Paper No. 40, *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years* (Hershfield, 1961), for the Ohio River basin. The study involves the completion of specific tasks including collecting and performing quality control of data, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

B. Study Area

The study area covers 13 states completely and parts of nine additional bordering states. The Susquehanna River and Delaware River basins are also included in the study area.

The study area is divided into 16 near-homogeneous regions. Factors considered in defining the regions include:

1) the season(s) of highest precipitation,
2) the type of precipitation (e.g., general storm, convective, tropical storms or hurricanes, or a combination),
3) the climate,
4) the topography, and
5) the homogeneity of these factors in a single area.

The study area is displayed in Figure 1. The core and border states and regional boundaries are shown on the figure.

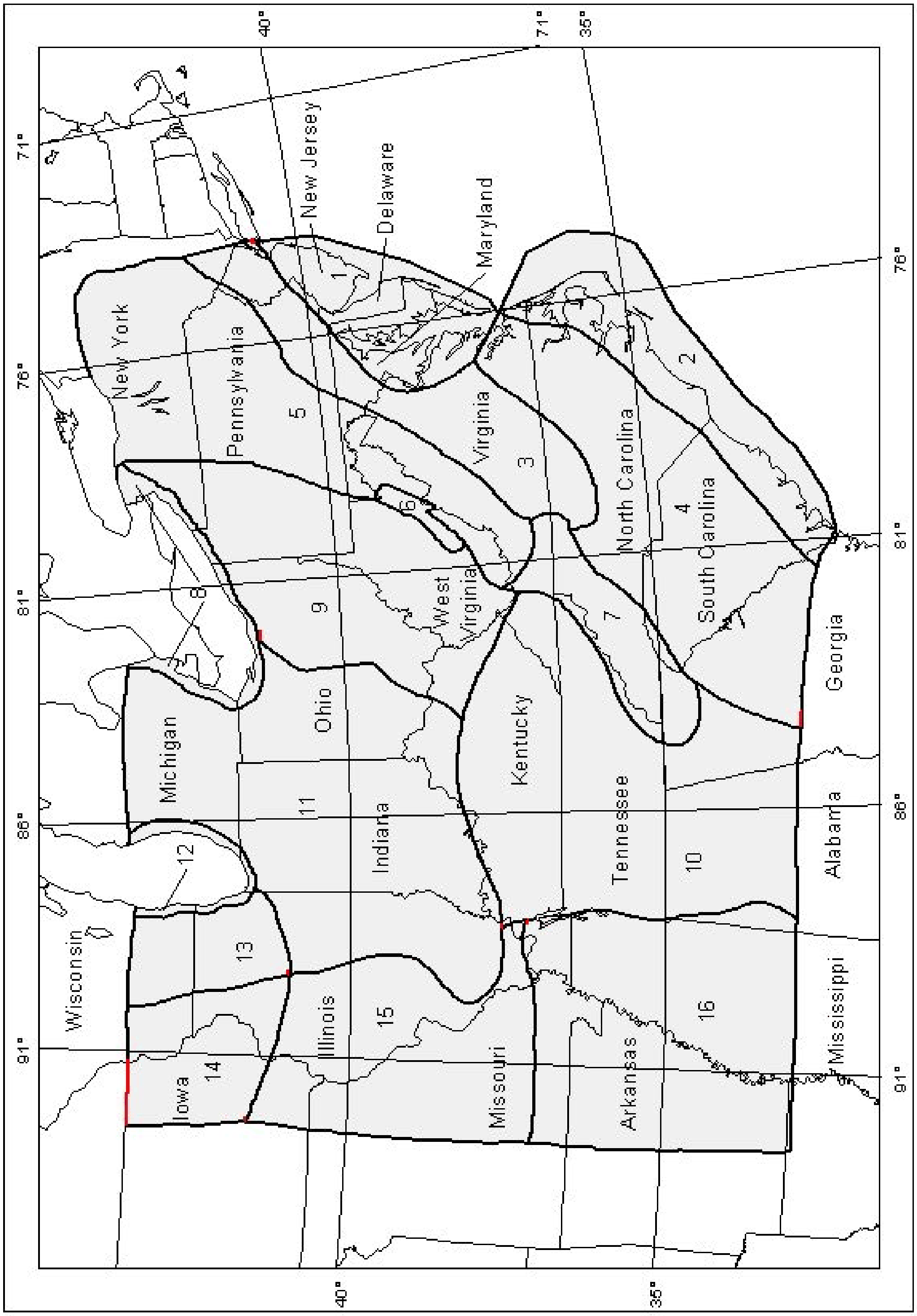


Figure 1. Ohio River study area and region boundaries.

II. TASK STATUS

The following sections discuss the status of each task and provide a short technical description of decisions made and tasks accomplished. The Appendix includes summaries of the various datasets as well as conversion factor information, given in the Fifth Progress report.

A. Data Collection and Quality Control

The daily, hourly and n-minute datasets are complete with data through November 1998. The daily data set was updated by correcting several suspicious data in terms of the temporal and spatial continuity based on discordancy analysis and graphical analysis of L-skewness versus L-kurtosis. An additional 294 daily stations have recently been evaluated and will be included in the precipitation frequency calculations.

Table 1. Information on daily, hourly and n-minute datasets.

	Daily	**Hourly**	**N-minute**
No. of stations	3269	984	76
Longest record length (yrs) **(Station ID)**	119 (20-0230)	99 (36-6993)	26 (44-8906)
Average record length (yrs)	56	42	24

B. Frequency Distribution Fitting Analyses

This task evaluates and selects the frequency distribution which provides the best fit for the data. A comprehensive study using L-moment statistics (Hosking and Wallis 1997) on goodness-of-fit has been carried out for both daily and hourly data for all durations and all regions. The three methods used in the study were: the x-test method based on a Monte Carlo data simulation by comparison of the deviation between the mean data point and a distribution in L-kurtosis; the four criteria method based on graphical analysis of L-skewness vs. L-kurtosis by comparison of deviations between each point and a distribution in L-kurtosis; the real-data-check method based on the comparison of the theoretical probabilities for a distribution with the empirical frequencies for the real data over a great number of stations in each region (Lin and Vogel 1993). The purpose of the study was to select a best-fitting distribution for the partial duration (PD) data.

C. Trend and Shift Statistical Analysis

Concerns about the impact of global warming and climate change on precipitation statistics bring awareness of the occurrence of trends and shifts in hydrological time series. As part of the data quality control for the Ohio River Basin study, trend and shift analyses were performed on the annual maximum (AM) precipitation data. A total of 2755 stations in 22 states were examined.

Generally, the AM precipitation time series data are free from linear trends and free from shifts in the mean for most stations in the Ohio River Basin at a 90% confidence level. Specifically, 1510 (or 84%) of 1797 tested stations are free from linear trends, and 437 (or 82%) of 531 tested stations are free from shifts in the mean. The trends and shifts were significant in approximately 15% of the stations (Lin and Julian 2001). Tables 2 and 3 give the results for the linear trend test and the mean shift test.

After completion of the trend and shift analysis, data quality control was performed on stations exhibiting a significantly high linear trend and/or shift in their AM precipitation time series data. Suspicious data were examined, but no need for corrections was found. The trend and shift analysis provided a view of the time series' possible impact on the frequency estimates.

Table 2. Linear trend test results.

States	Number of Stations/Trending Stations (%)				
	N_{Test}	N_{Trend}	N_{Up}	N_{Down}	$\%_{Trend}$
Alabama (AL)	51	9	6	3	17.6
Arkansas (AR)	54	7	7	0	13.0
Delaware (DE)	8	0	0	0	0
Georgia (GA)	65	13	13	0	20.0
Illinois (IL)	160	29	23	6	18.1
Indiana (IN)	118	17	15	2	14.4
Iowa (IA)	56	8	7	1	14.3
Kentucky (KY)	108	19	18	1	17.6
Maryland (MD)	45	5	3	2	11.1
Michigan (MI)	57	10	9	1	17.5
Mississippi (MS)	58	9	9	0	15.5
Missouri (MO)	77	9	8	1	11.7
New Jersey (NJ)	50	6	2	4	12.0
New York (NY)	91	12	5	7	13.2
North Carolina (NC)	132	24	21	3	18.2
Ohio (OH)	156	19	17	2	12.2
Pennsylvania (PA)	149	16	5	11	10.7
South Carolina (SC)	77	17	12	5	22.1
Tennessee (TN)	88	21	20	1	23.9
Virginia (VA)	80	15	10	5	18.8
West Virginia (WV)	76	8	7	1	10.5
Wisconsin (WI)	41	9	7	2	22.0
Sum	**1797**	**282**	**224**	**58**	**Avg. = 15.7**

N_{Test} means the number of stations tested.
N_{Trend} means the number of stations showing a trend.
N_{Up} means the number of stations showing an upward trend.
N_{Down} means the number of stations showing a downward trend.
$\%_{Trend}$ means percentage of trending stations (N_{Trend}) to tested stations (N_{Test}).

Table 3. Mean shift test results.

States	Number of Stations / Change in Mean (%)				
	N_{Total}	N_{Shift}	N_{Up}	N_{Down}	$\%_{Change}$
Alabama (AL)	5	1	1	0	25.0
Arkansas (AR)	18	4	4	0	15.4
Delaware (DE)	2	0	0	0	0.0
Georgia (GA)	12	5	5	0	17.5
Illinois (IL)	69	11	10	1	16.0
Indiana (IN)	46	6	4	2	8.2
Iowa (IA)	24	9	9	0	16.5
Kentucky (KY)	31	8	8	0	17.4
Maryland (MD)	11	2	1	1	-1.4
Michigan (MI)	28	5	5	0	18.2
Mississippi (MS)	13	4	4	0	15.8
Missouri (MO)	28	3	2	1	5.8
New Jersey (NJ)	20	2	1	1	0.7
New York (NY)	18	4	2	2	0.7
North Carolina (NC)	35	4	3	1	27.6
Ohio (OH)	75	12	11	1	13.1
Pennsylvania (PA)	25	3	2	1	3.2
South Carolina (SC)	22	4	4	0	20.8
Tennessee (TN)	9	3	3	0	16.5
Virginia (VA)	17	3	3	0	14.8
West Virginia (WV)	9	0	0	0	0.0
Wisconsin (WI)	15	1	1	0	16.7
Sum	**531**	**94**	**83**	**11**	**Avg. = 13.4**

N_{Total} means the number of stations tested.
N_{Shift} means the number of stations showing a shift.
N_{Up} means the number of stations showing an upward shift.
N_{Down} means the number of stations showing a downward shift.
$\%_{Change}$ means average change in the mean for the stations that have shift.

D. Mapping Analyses

Currently, the HDSC is exploring the possibility of using spatial interpolation tools such as the Parameter-elevation Regressions on Independent Slopes Model (PRISM). If, and before, a major shift from hand-analyzing maps to a numerical model technique occurs, comprehensive testing will be undertaken. This will include the exploration of other spatial interpolation tools as well as PRISM.

PRISM is an analytical tool that uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of climatic parameters, such as precipitation. PRISM is designed to map climate in various situations, including high mountains, rain shadows, inversions, coastal regions, and other complex climatic regimes. The predicted climate element (y) is determined from a linear equation that is based on station data (y) and elements related to elevation (x). PRISM was developed by the Spatial Climate Analysis Service (SCAS) at Oregon State University (OSU). PRISM is proprietary and copyrighted by OSU SCAS.

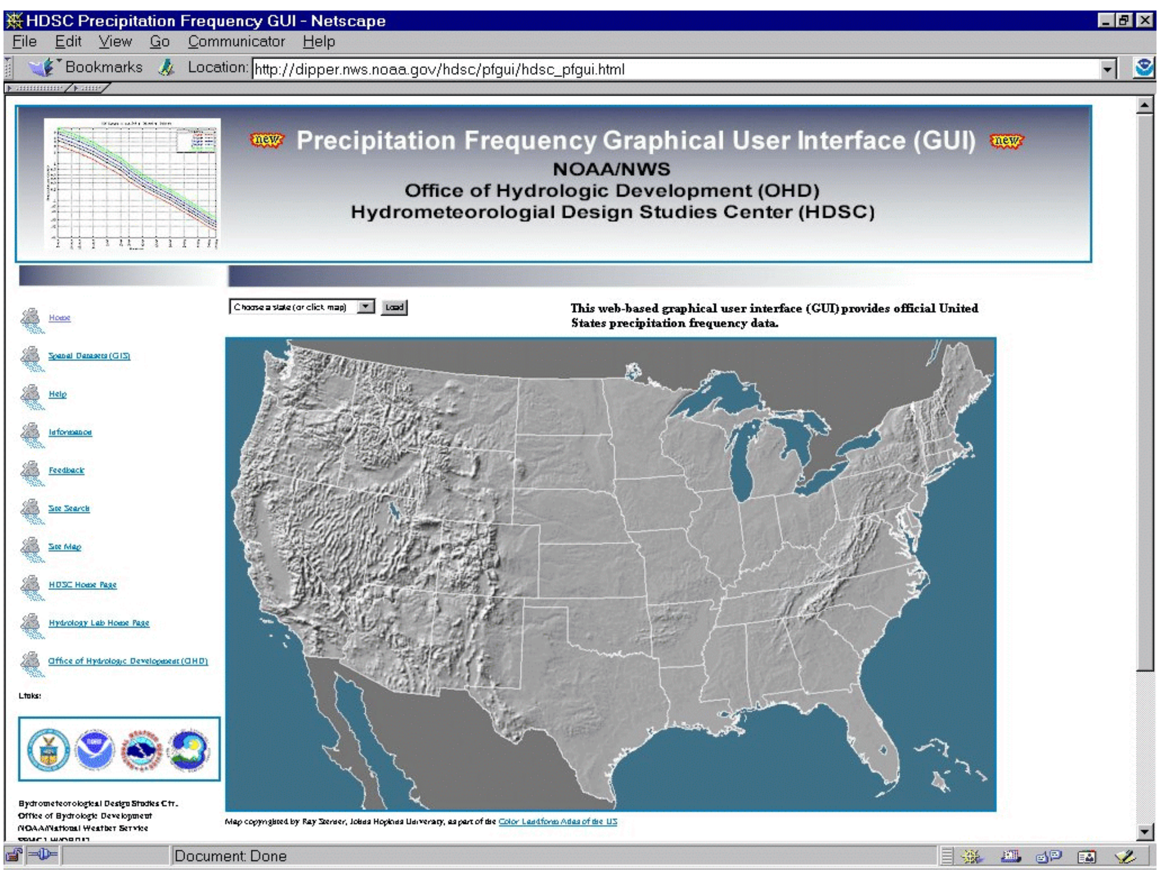
III. INTERNET-BASED GRAPHICAL USER INTERFACE (GUI)

The results of the Ohio River Basin study will be available on the HDSC graphical user interface (GUI) once mapping is complete (including review), and the data are added to the system. At present, all states can be selected. However, where studies are not yet in place, information on existing precipitation frequency maps, namely TP40 and NOAA Atlas 2 (Miller et al 1973), is given. The GUI was developed for the Semiarid Precipitation Frequency Study, which is now in a review process.

The GUI is now much faster and more flexible than a few months ago due to revised software (see Figure 2). The GUI displays precipitation frequency values as well as intensity-duration-frequency (IDF) curves and tables. Instead of being Java-based, the on-line precipitation frequency GUI now operates with Perl, cgi-bin scripts and JavaScript.

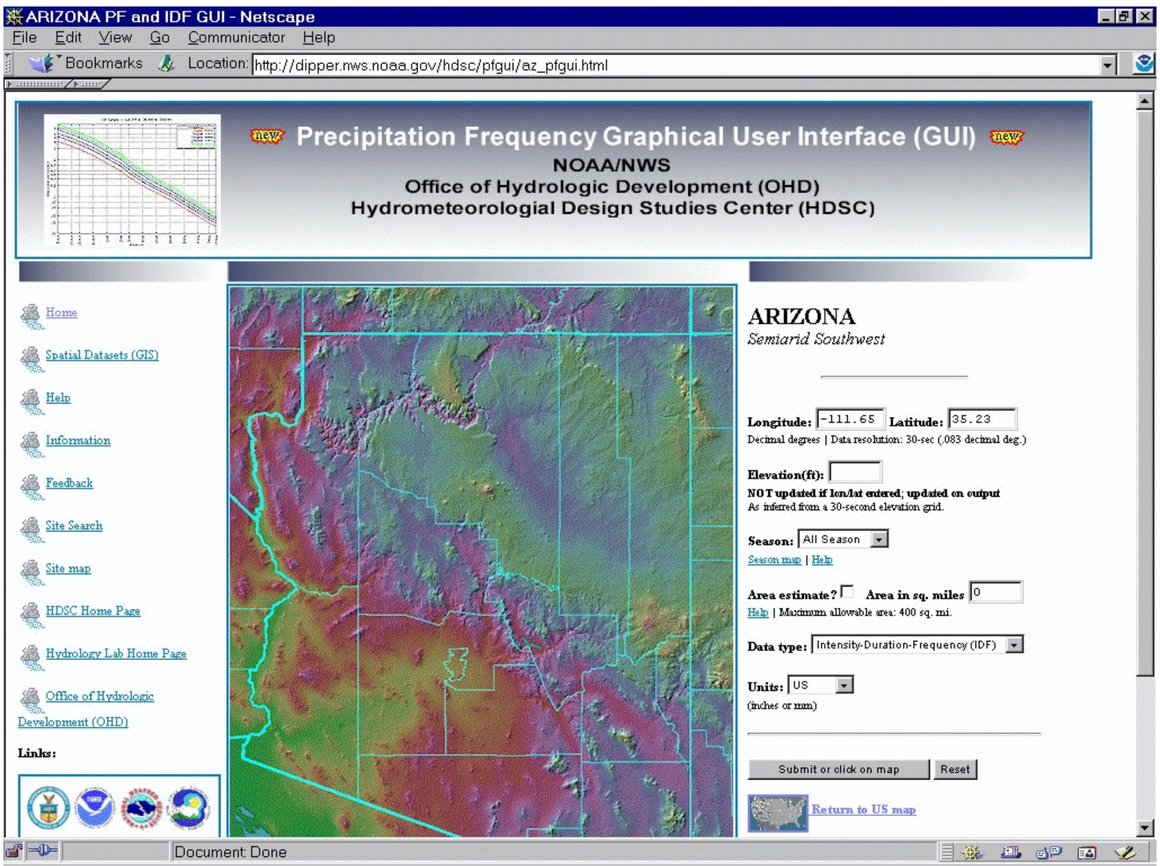
The GUI and its associated web pages are installed and maintained on a dedicated web server at the National Weather Service headquarters in Silver Spring, Maryland.

Figure 2. HDSC precipitation frequency GUI home page.

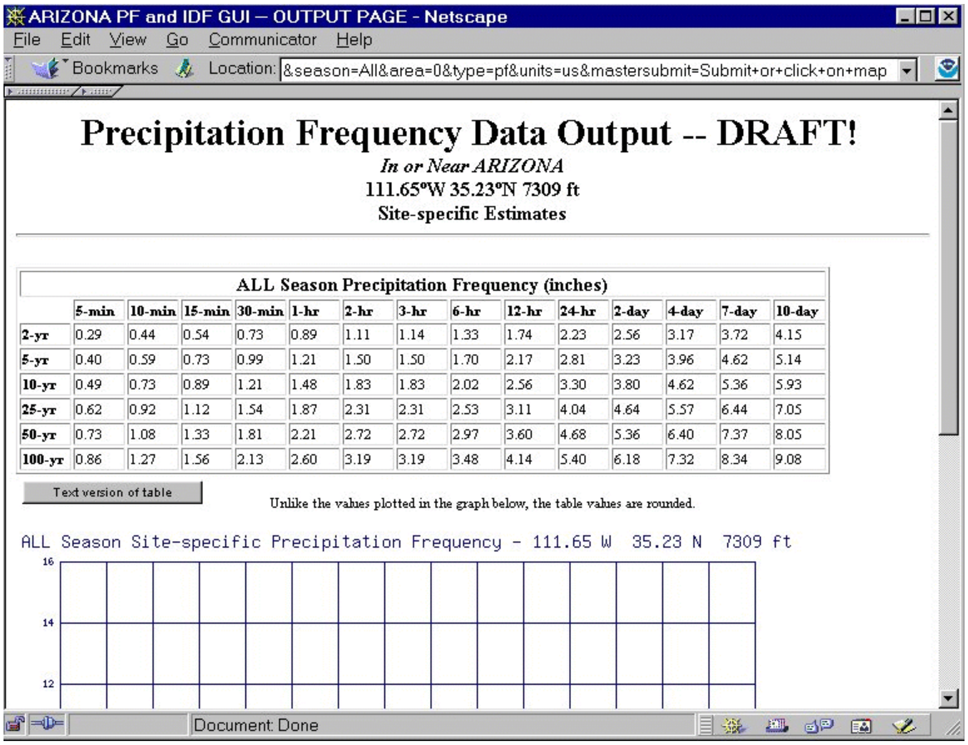


The user chooses a point on the map (or manually enters the longitude and latitude) and selects units (inches or millimeters) and season (warm, cool or all). For the chosen location, the output includes elevation and region, as well as the frequency information. An example from the Semiarid Study, specifically Flagstaff, Arizona, follows (See Figures 3-7).

Figure 3. Arizona precipitation frequency GUI page with shaded relief map and options window.



The new GUI provides output for durations of 5-min to 10-days on a single page. An option to save the data in a comma-delimited format exists for any further processing. Since the generated graph is in a GIF format, it can be saved as well as printed.



ALL Season Precipitation Frequency (inches)

	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr	2-day	4-day	7-day	10-day
2-yr	0.29	0.44	0.54	0.73	0.89	1.11	1.14	1.33	1.74	2.23	2.56	3.17	3.72	4.15
5-yr	0.40	0.59	0.73	0.99	1.21	1.50	1.50	1.70	2.17	2.81	3.23	3.96	4.62	5.14
10-yr	0.49	0.73	0.89	1.21	1.48	1.83	1.83	2.02	2.56	3.30	3.80	4.62	5.36	5.93
25-yr	0.62	0.92	1.12	1.54	1.87	2.31	2.31	2.53	3.11	4.04	4.64	5.57	6.44	7.05
50-yr	0.73	1.08	1.33	1.81	2.21	2.72	2.72	2.97	3.60	4.68	5.36	6.40	7.37	8.05
100-yr	0.86	1.27	1.56	2.13	2.60	3.19	3.19	3.48	4.14	5.40	6.18	7.32	8.34	9.08

Figure 4. PF output for point estimates.

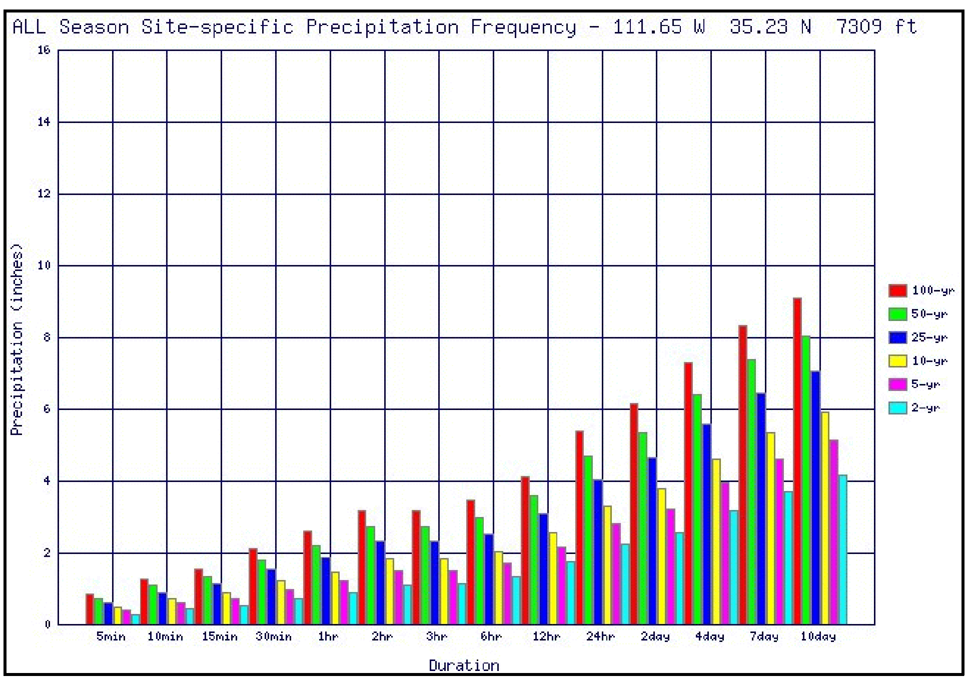
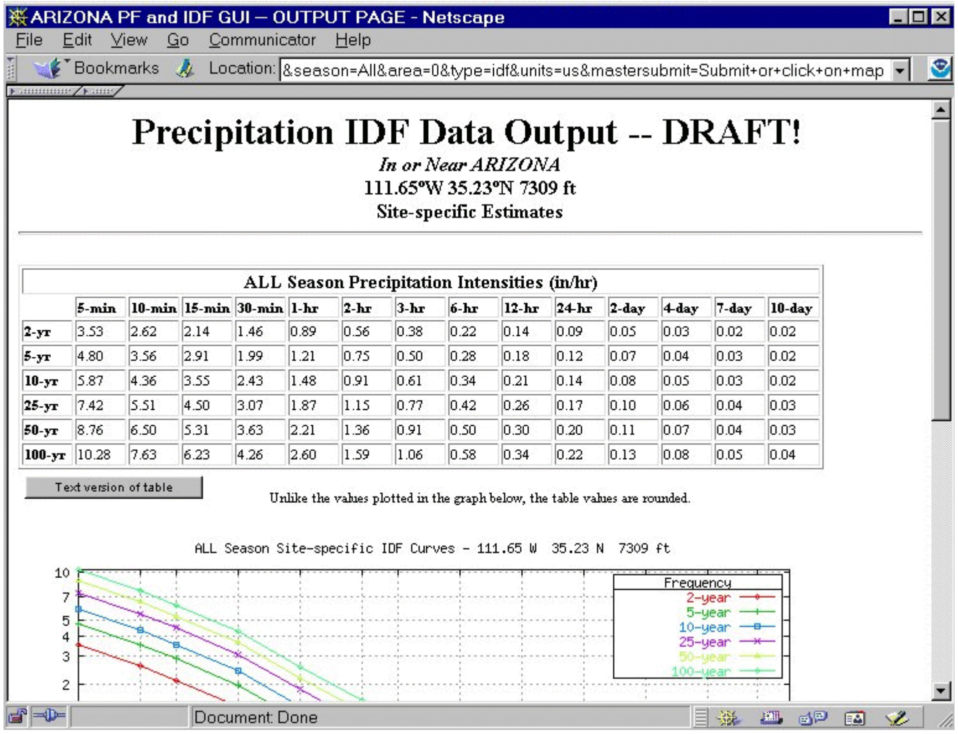


Figure 5. Plot of PF for point estimates.



ALL Season Precipitation Intensities (in/hr)

	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr	2-day	4-day	7-day	10-day
2-yr	3.53	2.62	2.14	1.46	0.89	0.56	0.38	0.22	0.14	0.09	0.05	0.03	0.02	0.02
5-yr	4.80	3.56	2.91	1.99	1.21	0.75	0.50	0.28	0.18	0.12	0.07	0.04	0.03	0.02
10-yr	5.87	4.36	3.55	2.43	1.48	0.91	0.61	0.34	0.21	0.14	0.08	0.05	0.03	0.02
25-yr	7.42	5.51	4.50	3.07	1.87	1.15	0.77	0.42	0.26	0.17	0.10	0.06	0.04	0.03
50-yr	8.76	6.50	5.31	3.63	2.21	1.36	0.91	0.50	0.30	0.20	0.11	0.07	0.04	0.03
100-yr	10.28	7.63	6.23	4.26	2.60	1.59	1.06	0.58	0.34	0.22	0.13	0.08	0.05	0.04

Figure 6. IDF output for point precipitation estimates.

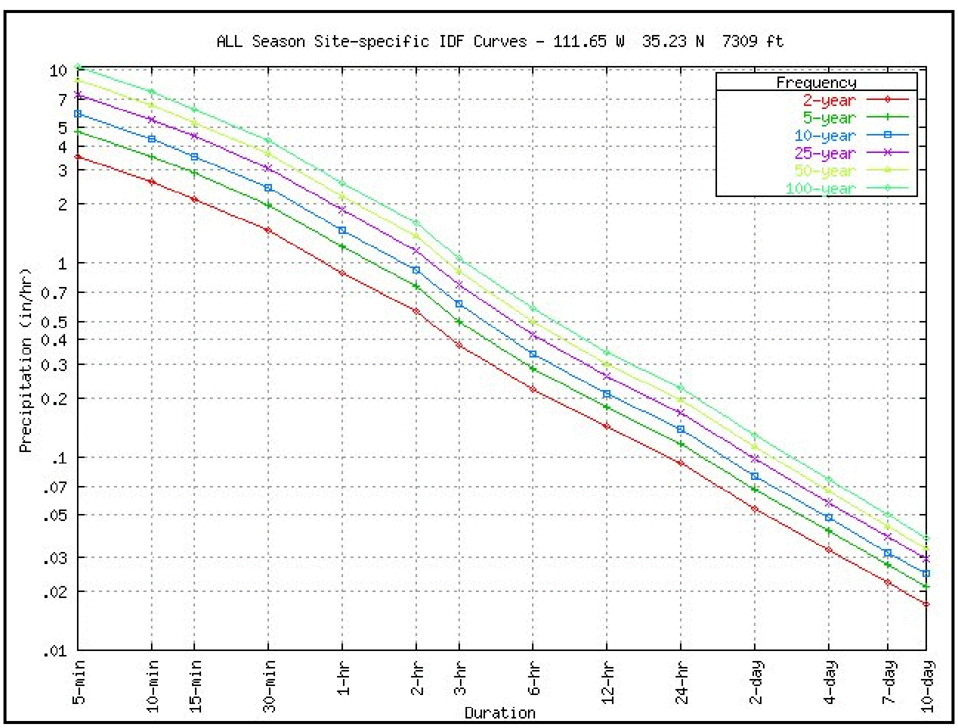


Figure 7. IDF curves for point precipitation estimates.

References

Hershfield, D.M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, *Technical Paper No. 40*, U.S. Weather Bureau, Washington, DC.

Hosking, J.R.M. and J.R. Wallis, 1997: Regional Frequency Analysis, An approach based on L-moments, Cambridge University Press, NY, 224 pp.

Lin, B. and L.T. Julian, 2001: Trend and Shift Statistics on Annual Maximum Precipitation in Ohio River Basin over the Last Century, *Symposium on precipitation extremes: precipitation, impacts, and responses*, AMS, Albuquerque, NM, 14-18 January 2001.

Lin, B. and J.L. Vogel, 1993: A comparison of L-moments with method of moments, *Engineering Hydrology Symposium Proceedings*, ASCE, San Francisco, CA, 25-30 July, 1993.

Miller et al, 1973: Precipitation-frequency atlas of the western United States, NOAA Atlas 2, 11 volumes. National Weather Service, Silver Spring, MD.

Appendix

An additional 294 stations, primarily in Regions 9, 10 and 11 (i.e., Illinois, Indiana, Kentucky, Ohio, Tennessee, and West Virginia) may be added.

Updated as of 19 March 2001		
Region	No. stations with $\geq$ 1 data years	No. stations with $\geq$ 20 data years
1	169	121
2	52	45
3	260	197
4	262	218
5	598	409
6	20	10
7	271	174
8	41	30
9	443	321
10	555	460
11	390	348
12	31	26
13	72	67
14	105	87
15	242	201
16	335	261
Total	3846	2976

Table A. Daily stations with $\geq$ 1 data years and $\geq$ 20 data years.

The hourly data collection and formatting process is complete for all 16 regions in the Ohio River Basin study area.

Updated as of 19 March 2001		
Region	No. stations with ≥ 1 data years	No. stations with ≥ 20 data years
1	55	25
2	18	11
3	105	54
4	98	54
5	292	148
6	6	3
7	94	35
8	24	11
9	256	137
10	266	112
11	273	173
12	26	18
13	29	17
14	56	36
15	124	70
16	129	80
Total	1851	984

Table B. Hourly stations with ≥ 1 data years and ≥ 20 data years.

The n-minute (i.e., 5-minute, 10-minute, 15-minute, 30-minute) data collection and formatting process is complete for all 16 regions in the Ohio River Basin study area.

Updated as of 19 March 2001	
Regio n	No. stations with ≥ 10 data years
1	5
2	3
3	6
4	7
5	6
6	1
7	1
8	4
9	7
10	9
11	10
12	2
13	3
14	3
15	4
16	5
Total	76

Table C. N-minute stations with ≥ 10 data years.

Conversion factors were determined based on comparisons of concurrent daily-hourly-minute precipitation data at co-located first-order stations in the Ohio River Basin. Conversion factors are used when converting daily data to 24-hour data before L-moment computations are performed.

Type of conversion factors		Projects	
		Ohio River Basin	**Semiarid Southwest**
Daily Conversion	1-day to 24-hour	***1.13***	***1.14***
	2-day to 48-hour	***1.04***	***1.03***
	Number of stations used for the factor	**86**	**17**
	Data threshold	**15-year**	**14-year**
Hourly Conversion	1-hour to 60-minute	***1.16***	***1.12***
	2-hour to 120-minute	***1.05***	***1.03***
	Number of stations used for the factor	**69 for 1-hour** **68 for 2-hour**	**12 for 1-hour** **13 for 2-hour**
	Data threshold	**15-year**	**14-year**

Table D. List of conversion factors.